IN THE UNITED STATES DISTRICT COURT
FOR THE WESTERN DISTRICT OF TEXAS
WACO DIVISION

Tomax AS, Plaintiff, VS. Turbo Drill Industries, Inc. d/b/a Scout Downhole Defendant.	§ § § § § § § § § § §	Case No.: 6:21-CV-260 COMPLAINT FOR PATENT INFRINGEMENT JURY TRIAL DEMANDED

COMPLAINT

Plaintiff Tomax, AS ("Plaintiff" or "Tomax"), by and through its undersigned attorney, hereby pleads the following claims against Defendant Turbo Drill Industries, Inc. d/b/a Scout Downhole.

Plaintiff alleges as follows:

NATURE OF THE ACTION

1. This is an action for direct infringement pursuant to 35 U.S.C. 271(a) of U.S. Patent No. 7,578,360 titled "Dynamic Damper for Use in a Drill String."[1] This is also an action for direct infringement pursuant to 35 U.S.C. 271(a) of U.S. Patent No. 10,533,376[2] titled "Regulating Device and a Method of Using Same in a Borehole."

[1] Tomax's U.S. Patent No. 7,578,360 is attached as Exhibit A and forms a part of this Complaint.
[2] Tomax's U.S. Patent No. 10,533,376 is attached as Exhibit B and forms a part of this Complaint.

PARTIES

2. Plaintiff Tomax AS ("Plaintiff" or "Tomax") is a corporation organized under the laws of the Kingdom of Norway whose headquarters is located at Kanalsletta 2, 4033, Stavanger, Norway 4067. Plaintiff Tomax is the owner, by assignment, of U.S. Patents Nos. 7,578,360 and 10,533,376.

3. Defendant Turbo Drill Industries, Inc. d/b/a Scout Downhole ("Defendant" or "Scout") is a Texas for-profit corporation whose registered agent is Kenneth R. Holt, who has a service address filed with the Texas Secretary of State as 3200 Southwest Freeway, Suite 3200, Houston, Texas 77027. Scout's headquarters is located at 1125 Beach Airport Road, Conroe, Texas 77301. In addition, Scout has a regular and established place of business located at 8415 West I-20, Midland, Midland County, Texas 79706, which is located within the Western District of Texas. Plaintiff Tomax and Defendant Scout are direct competitors in the marketplace.

JURISDICTION & VENUE

4. This is an action for patent infringement arising under the patent laws of the United States of America, Title 35 of the United States Code, and in particular, 35 U.S.C. §271.

5. This Court has original and exclusive subject matter jurisdiction pursuant to 28 U.S.C. §1331 (federal question) and §1338 (Patent Act violations).

6. Upon information and belief, this Court has personal jurisdiction over Defendant Scout because Scout both resides in and maintains a regular place of business in the Western District of Texas.

The Inventors Recognize the Problem & Develop the Solution to "Stick-Slip"

7. Humans have been drilling wells for many centuries. For example in 1833-1841, French engineers required eight years to drill an approximately 1,771-foot deep water well in Grenelle, France using a dry rotary auger. The dry rotary auger advanced at less than one foot per day. This well was likely drilled by hand or animal powered. In modern terms, the rate of penetration (ROP) of the auger was only a fraction of an inch per hour.

8. In the oil & gas industry, drilling rigs used to drill oil & gas wellbores can have rental costs from the tens of thousands of dollars per day for a land based rig to many millions of dollars per day for off-shore rigs. It is self-evident that the more quickly the rig drills the well, the lower the total rental costs. Consequently, an innovation that increases ROP is highly desirable. However, an innovation that temporarily increases ROP may also reduce drill bit life. Each time the drill bit is "tripped" out of the borehole, and replaced with a fresh drill bit, can take many hours of expensive rig time. Obviously, when the well is being "tripped," it is not increasing the depth/length of the borehole and is therefore highly undesirable non-productive time (NPT). NPT is the bane of any industry and particularly the oil & gas industry. Consequently, any innovation that reduces NPT and increases ROP is valuable and those drilling oil & gas wells will flock to adopt this technology.

9. In more recent times, tri-cone drill bits, first patented by the Hughes Tool Company in 1909, have increased ROP and made deep wells possible.

10. Beginning in the approximately the 1990's, polycrystalline (PDC) drill bits have been increasingly used to drill oil & gas wells. PDC bits have many advantages over tri-cone bits, but these advantages have potential drawbacks. The use of PDC drill bits requires an increase in the weight-on-bit (WOB) to establish engagement in hard rock. The greater the WOB, the more deeply the drill bit's cutters depth of cut is. Depth of cut may be generally thought of as how "deep a bite" into the rock the drill bit's cutters are taking with each rotation. If the depth of cut is deeper than is desirable, the drill bit will potentially stop turning. This is referred to as "stick." Of course, the rotary table, which drives the rotation of the drill string, does not stop turning when the drill bit "sticks." As forces build up, the bit suddenly begins to rotate. This sudden rotation is referred to as "slip." These two phenomenon are collectively referred to as "stick-slip." Phrased differently, the drill bit "sticks" and then "slips," which is a "stop-and-start" motion of the drill bit. "Stick-slip" may also be thought of as a "jerking" motion of the drill bit. In addition to the temporarily increased rate of rotation which occurs during "slip," stick-slip also results in increased frictional heating of the cutting elements of the drill bits. PDC drill bit cutters, usually industrial diamond, are sensitive to temperatures above 350° Centigrade and tend to degrade above this temperature. Because the drill bit can be thousands of feet below the rotary table, which produces the torque-on-bit (TOB) and WOB, it is problematic to fine tune and control the drill bit from the surface.

11. Before Tomax developed its successful solution, a variety of techniques unsuccessfully attempted to solve the stick-slip problem. An example of one such

solution was a reduction in the so-called "angle of attack" of the cutting elements of the drill bit. The drawback of this solution is that the drill bit's cutters cut less depth with each rotation. Consequently, the rate-of-penetration (ROP) is reduced. As discussed above, this is undesirable.

12. Tomax recognized these problems and secured funding to build prototypes and test them at a test rig in Stavanger, Norway. After testing, Tomax was able to convince operators to test the new technology offshore in oil & gas wells.
13. By 2019, Tomax had a turnover of 30 million ($USD) per year. Currently, Tomax has a 25,000 sq.ft. facility in Rosharon, Texas and an 8,000 sq.ft. facility in Odessa, Texas as well as offices in Stavanger, Norway. Before the current Covid induced slump, Tomax had 35 total employees. Currently, Tomax has 25 employees in the United States. In addition, Tomax's AST tool, which incorporates the patented technology, has been used on more than 4900 occasions.

<u>Defendant Scout Rents Tomax's AST Tool & Likely Copies It</u>

14. At least as early as May 19, 2019, Defendant Scout rented Tomax's patent protected AST tool and operated the AST tool at Rig H&P 616 – Ameredev, on the Camellia Fed Com 26-36-21, in Lea County, New Mexico.
15. Throughout the first seven months of 2020 (January 1-July 31, 2020, Defendant Scout rented and used Tomax's AST tool on more than 20 different wells throughout the United States. All told, during the first seven months of 2020, Defendant Scout's use of Tomax's AST tool totaled more than 1288 hours.

16. Upon information and belief, Defendant Scout introduced its knock-off "Steady Torque" tool in the latter half of 2020.

17. On November 5, 2020, Håkon Skjelvik, Tomax's president, wrote to Defendant Scout concerning Scout's infringement of Tomax's U.S. Patents Nos. 7,578,360 and 10,533,376. Defendant's president Myles Woloshyn responded on November 20, 2020. As such, Defendant Scout has actual knowledge of the patents in questions and any continued infringement is therefore willful patent infringement.

Defendant Scout Has Used its Infringing Knock-off Steady Torque Tool in the Western District of Texas

18. Upon information and belief, Defendant Scout used its knock-off SteadyTorque tool for Anadarko Energy & Production Onshore, LLC, at Phantom (Wolfcamp) field, in Loving County, Texas, thereby infringing at least Claims 1 and 4 of Tomax's U.S. Patent No. 7,578,360 and at least Claims 1, 5, 9, and 11 of Tomax's U.S. Patent No. 10,533,376 in October 2020.

19. Upon information and belief, Defendant Scout used its knock-off SteadyTorque tool for Diamond Back Energy, at Well 1WB, lease name Paper Rings 136-137 A, in Martin County, Texas, thereby infringing at least Claims 1 and 4 of Tomax's U.S. Patent No. 7,578,360 and at least Claims 1, 5, 9, and 11 of Tomax's U.S. Patent No. 10,533,376 in October 2020.

20. As discussed above, Defendant Scout has a regular and established place of business located at 8415 West I-20, Midland, Midland County, Texas 79706, which is within the Western District of Texas.

21. Therefore, Defendant Scout has both committed acts of infringement (in at least Loving County and Martin County) and maintains a regular place of business within the Western District of Texas and venue is appropriate in the Western District of Texas pursuant to 28 U.S.C. §1400.

COUNT 1 - PATENT INFRINGEMENT

22. Plaintiff Tomax incorporates the above paragraphs by reference.
23. This is a claim for direct infringement of U.S. Patent No. 7,578,360, pursuant to 35 U.S.C. §271(a).
24. Defendant Scout's Steady Torque Tool infringes at least one claim of U.S. Patent No. 7,578,360.

COUNT 2 - PATENT INFRINGEMENT

25. Plaintiff Tomax incorporates the above paragraphs by reference.
26. This is a claim for direct infringement of U.S. Patent No. 10,533,376, pursuant to 35 U.S.C. §271(a).
27. Defendant Scout's Steady Torque Tool infringes at least one claim of U.S. Patent No. 10,533,376.

JURY DEMAND

Pursuant to Fed.R.Civ.P. 38, Plaintiff Tomax requests a jury trial on all issues so triable.

PRAYER FOR RELIEF

Plaintiff Tomax asks that this Court rule in its favor and grant the following relief:

a. Judgment that one or more claims of U.S. Patent No. 7,578,360 have been infringed either literally or under the Doctrine of Equivalents;

b. Judgment that one or more of the claims of U.S. Patent No. 10,533,376 have been infringed either literally or under the Doctrine of Equivalents;

c. For an accounting of Defendant Scout's infringing activity;

d. Judgment that Defendant Scout account for and pay to Plaintiff Tomax all damages and costs incurred by Plaintiff Tomax and caused by Defendant Scout's infringing activities;

e. An award of pre-judgment and post-judgment interest;

f. A preliminary injunction and a permanent injunction enjoining Defendant Scout, its officers, agents, employees, directors, representatives, and all those acting in concert with Defendant Scout from infringing U.S. Patent No. 7,578,360 and U.S. Patent No. 10,533,376;

g. That this Court find, pursuant to 35 U.S.C. §284, that Defendant Scout's infringement was willful and triple any damages award;

h. That this Court find that, pursuant to 35 U.S.C. §285, that this is an exceptional case and award Plaintiff Tomax its attorneys' fees and, if appropriate, a trebling of any attorneys' fees award; and,

i. Any such further relief as is just and proper under the circumstances.

Respectfully submitted,

/s/Malcolm E. Whittaker
Malcolm E. Whittaker

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ATTORNEYS FOR PLAINTIFF TOMAX AS

EXHIBIT A – U.S. PATENT NO. 7,578,360

US007578360B2

(12) **United States Patent**
Haughom

(10) **Patent No.: US 7,578,360 B2**
(45) **Date of Patent: Aug. 25, 2009**

(54) **DYNAMIC DAMPER FOR USE IN A DRILL STRING**

(76) Inventor: **Per Olav Haughom**, Høgåsen 12, Tonstad (NO) N-4440

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 301 days.

(21) Appl. No.: **10/548,928**

(22) PCT Filed: **Apr. 14, 2003**

(86) PCT No.: **PCT/NO03/00121**

§ 371 (c)(1),
(2), (4) Date: **Sep. 12, 2005**

(87) PCT Pub. No.: **WO2004/090278**

PCT Pub. Date: **Oct. 21, 2004**

(65) **Prior Publication Data**

US 2006/0185905 A1 Aug. 24, 2006

(51) **Int. Cl.**
E21B 17/07 (2006.01)

(52) **U.S. Cl.** **175/325.3**; 175/321; 175/323

(58) **Field of Classification Search** 175/323, 175/102, 310, 388, 101, 106, 322
See application file for complete search history.

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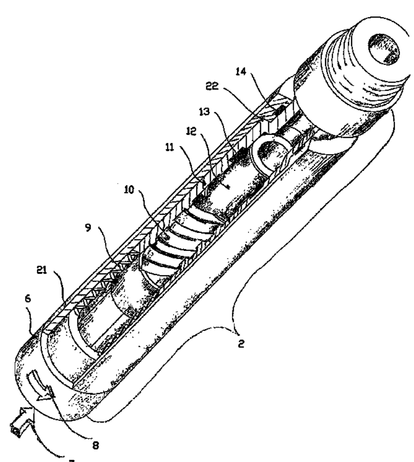
Primary Examiner—Jennifer H Gay
Assistant Examiner—Cathleen R Hutchins
(74) *Attorney, Agent, or Firm*—Andrus, Sceales, Starke & Sawall, LLP

(57) **ABSTRACT**

A dynamic damper for installation in a drill string (**1**), the purpose of which damper is to reduce the risk of jamming the drill bit (**5**), thereby avoiding damages in the event of unwanted extreme oscillations and rotational speed of the drill string caused by uncontrolled release of torsional energy in the drill string when the drill string suddenly breaks free of the jam. For this purpose, the damper is constructed from an outer and an inner string section (**11**) and (**12**), supported concentrically and interconnected through a helical threaded connection (**10**), so that relative rotation between the sections caused by torque (**8**) will give an axial movement that lifts and loosens the drill bit from the bottom of the hole in critical jamming situations. The spring (**9**) maintains the outer string section in an axial position against the shoulder (**22**). A hydraulic damping effect on the axial movements is achieved by oil volumes (**16**) and (**17**) being interconnected through narrow bores (**18**). Logging of the damping function is carried out by sensor (**20**), which registers and stores data to be read when the damper is retrieved to the surface.

7 Claims, 3 Drawing Sheets



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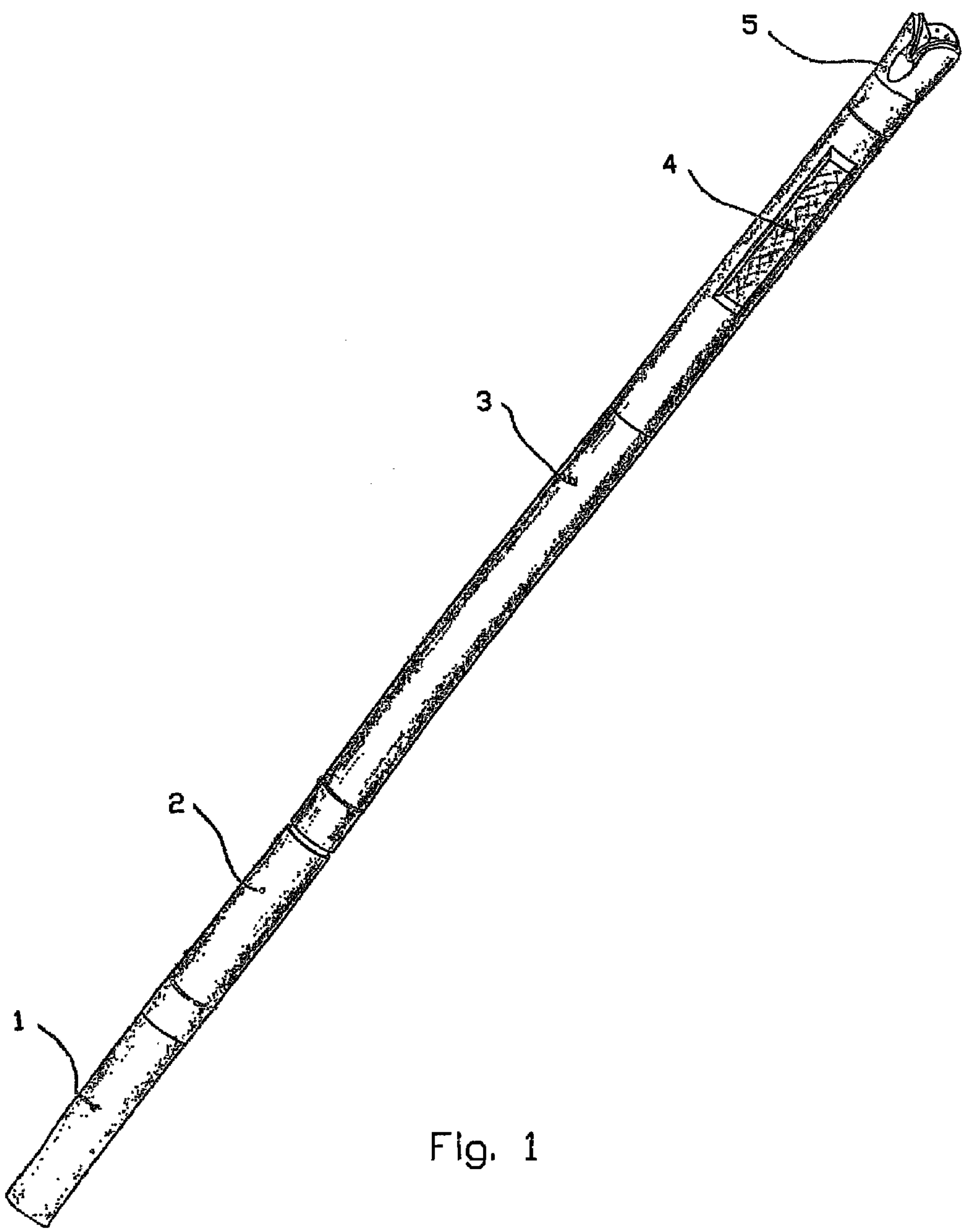

Fig. 1

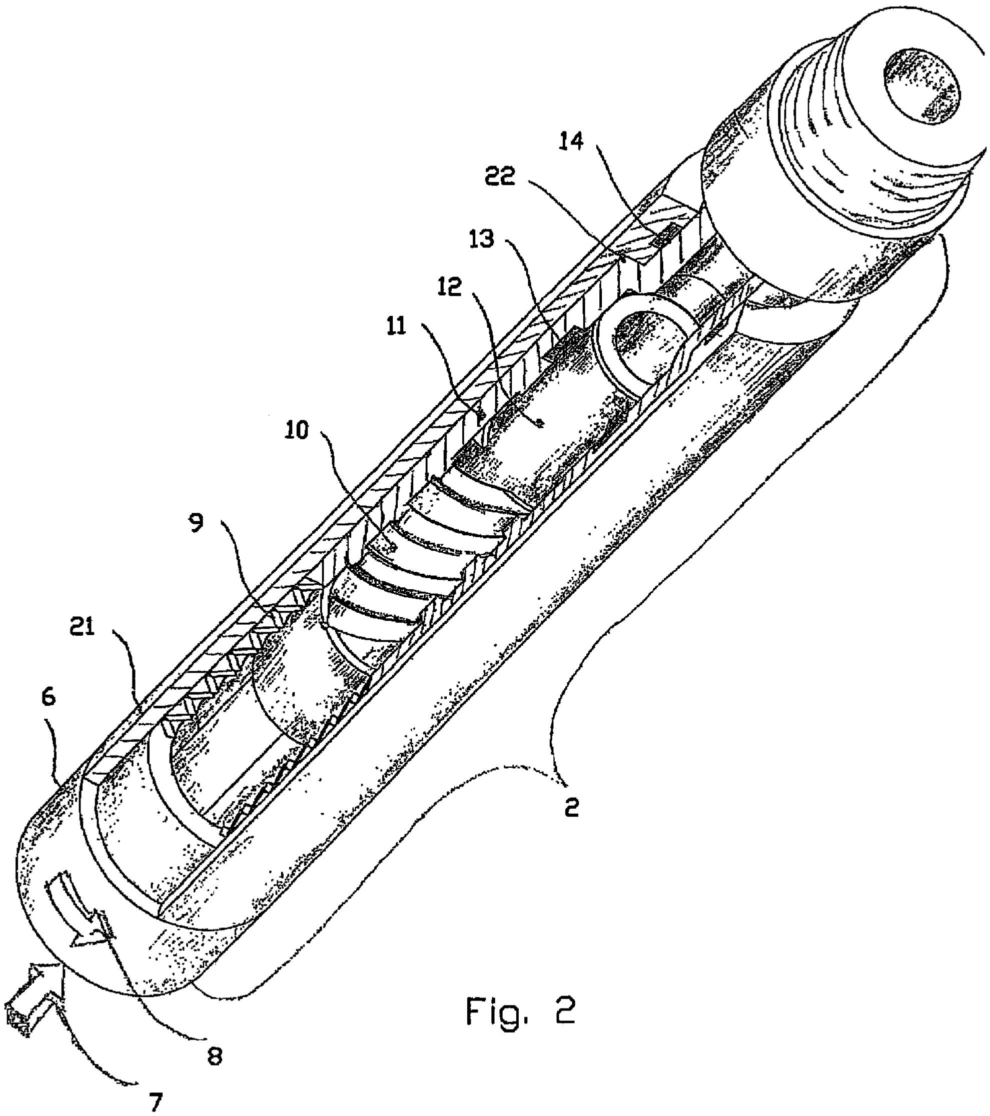

Fig. 2

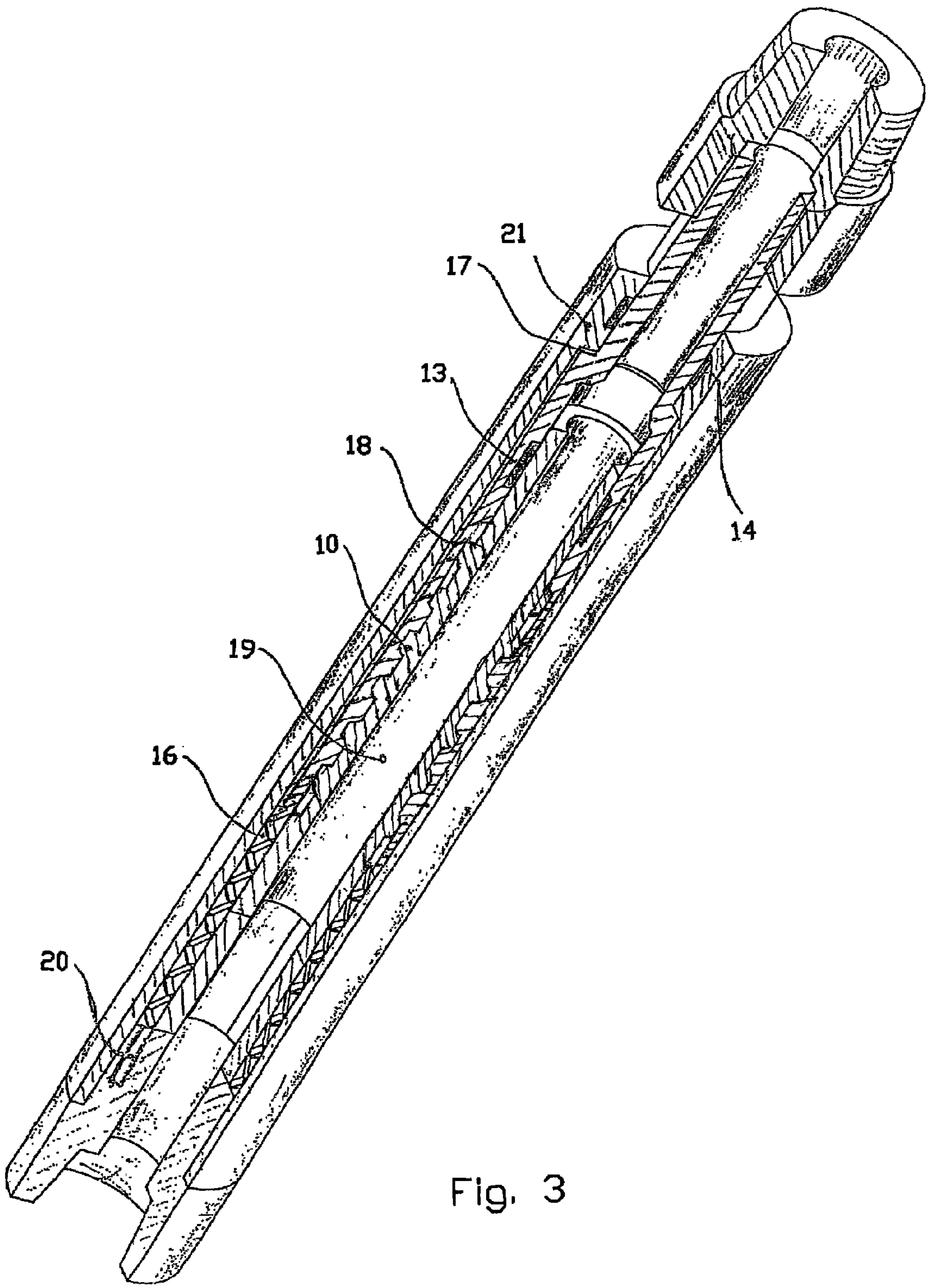

Fig. 3

DYNAMIC DAMPER FOR USE IN A DRILL STRING

CROSS REFERENCE TO RELATED APPLICATION

The present application is the U.S. national stage application of International Application PCT/NO2003/000121, filed Apr. 14, 2003, which international application was published on Oct. 21, 2004 as International Publication WO 2004/090278.

BACKGROUND OF THE INVENTION

This invention regards a dynamic damping device for use in a drill string, designed especially for use when drilling for hydrocarbons in sedimentary rocks.

Known dynamic dampers are extensively used to dampen oscillations that arise in mechanical constructions subjected to variable loads. In a drill string having a length of several thousand metres, oscillations can arise as a result of variations in the torque along the drill string.

Variations in torque may be due to different frictional conditions along the string and drilling through formations of different hardness, causing the moment on the drill bit to vary. Such uncontrollable variations in torque will in turn generate oscillations that exert great forces and vibrations on the drill string, in particular when the oscillations resonate with the natural oscillations of the drill string.

The use of more modern and more powerful rotary machines over the last years has resulted in the drill string now being subjected to considerably greater strain, with a consequent increase in the risk of damage caused by uncontrolled oscillations and vibrations.

A particular problem arises when the drill bit hits a formation that is difficult to penetrate, and jams. The drill string is turned by torque from the drilling machine on the surface, and the string builds up energy which is released when the drill suddenly breaks loose. All the stored energy is released through uncontrolled rotation, and the lower part of the drill string may reach extreme rotational speeds that can cause damage to the drilling equipment. Today's controlled drilling systems include a lot of electromechanical equipment that is especially susceptible to damage when subjected to this type of strain.

SUMMARY OF THE INVENTION

In relation to prior art, the object of the invention is to provide a solution that reduces the risk of the drill bit getting jammed, and of accumulated energy stored as torque in the drill string being released in the form of uncontrolled rotation.

This is achieved in accordance with the invention, by a dynamic damper being installed in the drill string, above the measuring equipment used for directional control. This damper consists of an inner cylindrical string section with threads that connect this to the upper section of the drill string, which in turn is connected to the rotary machine on the surface. An outer cylindrical string section is supported concentrically on the inner string section and connected to a lower section of the drill string towards the drill bit, through a threaded connection. The outer and inner string sections are engaged through a spiral trapezoidal threaded connection, so that relative rotation between the string sections will cause a relative axial movement between the two parts. A spring is disposed between the outer and inner string sections and pre-tensioned, so that axial movement between the outer and

inner string sections occurs only when axial force and moment or a combination of these exceed a predetermined value. Externally of the outer string section there is provided a cylindrical jacket connected to the inner string section through a threaded connection, such that the jacket protects the outer and inner string sections while at the same time constituting a limitation for the axial movement between the outer and inner string sections.

Between the outer and inner string sections there are two volumes filled with oil and interconnected in a manner such that axial movement will cause forced displacement of liquid from one volume to the next through narrow passages. This has an intended dynamic damping effect on the movement.

When the present invention is installed in a drill string, torque caused by incipient locking of the drill bit will effect relative rotation between the outer and inner string sections when the moment exceeds a selected spring tension. This will result in an axial movement that lifts and loosens the drill bit from the bottom. When the drill bit comes loose, the moment is reduced and the spring will again push the drill bit towards the bottom of the borehole, thus generating torque resistance that prevents the accumulated torque in the drill string from "spinning" out of control.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be explained in greater detail in connection with the description of an embodiment and with reference to the enclosed drawings, in which:

FIG. **1** is a system overview with a dynamic damper installed in the drill string;

FIG. **2** shows a section through the outer string section; and

FIG. **3** shows a section through the outer and inner string sections.

DETAILED DESCRIPTION OF THE INVENTION

In the drawings, reference number **1** denotes a known drill string where the dynamic damper has been installed and is referred to by reference number **2**. The instrumentation section for directional control **3** is installed in an extension of the damper, towards the drill bit, while the extension of part **3** holds stabilizers nibs **4** and drill bit **5**.

The torque and the axial force transferred to the damper are indicated by reference numbers **8** and **7**. The end piece **6** attached to the drill string with a threaded connection transfers the forces to an inner string section **12**.

The inner and outer string sections are engaged through helical threads **10**, such that relative rotation of these parts will entail relative axial movement between the parts. A torsional spring **9** stops against the end piece **6** on the inner string section **12** and against the outer string section **11**. The spring forces the outer string section **11** to stop against the shoulder **22** of outer jacket **21**. Thus the outer string section **11** will be pre-tensioned between the spring **9** and the shoulder **22** in a manner such that the torque **8** combined with axial force **7** must exceed a given value before relative torsion between the outer and inner string sections will occur, causing the intended axial movement between these sections.

The cavity formed between the two string sections and the jacket **21** is filled with oil that is kept in place with respect to the surroundings by means of seals **13** and **14**. Volume **17** and volume **16** around the spring **9** are interconnected through narrow bores **18**, so as to bring about an intended damping effect on the axial movement.

A central bore **19** for drill mud passes through the inner and outer string sections.

In order to log the performance of the damper, a sensor **20** is provided to register and record data on oil pressure and spring force from the spring **9**. These data can then be read when the drill string is retrieved, and will give information about the performance of the damper.

The invention claimed is:

1. A dynamic damper installed in a drill string above a drill bit, the damper comprising:

an inner cylindrical string section having an upper end connected to an upper portion of the drill string;

an outer cylindrical string section supported concentrically on the inner string section and having a lower end connected to a lower portion of the drill string;

wherein the inner and outer string sections are engaged via a spiral trapezoidal threaded section oriented so that relative rotation between the string sections will cause relative axial movement between the string sections;

a spring disposed between the inner and outer string sections, the spring being pre-tensioned so that axial movement between the outer and inner string sections occurs only when combined axial force and torque on the string sections exceed a predetermined value;

a cylindrical jacket arranged externally on the outer string section and connected to the inner string section such that the jacket protects the inner and outer string sections and constitutes a limitation for axial movement between the inner and outer string sections;

two oil-filled volumes located between the inner and outer string sections and being connected such that relative axial movement of the inner and outer sections forces displacement of oil from one of the volumes to the other volume, thus dampening movement between the string sections;

wherein torque caused by locking of the drill bit attached to the lower portion of the drill string effects relative rotation between the inner and outer string sections when said torque exceeds a selected spring tension;

wherein said relative motion between the inner and outer string sections is an axial movement that lifts and loosens the drill bit from its locked position;

wherein said lifting and loosening of the drill bit reduces said torque such that the spring tension pushes the drill bit in a direction away from the damper.

2. The dynamic damper of claim **1**, wherein the spring is a torsion spring that has one end stopped against the inner string section and another end stopped against the outer string section.

3. The dynamic damper of claim **2**, wherein the torsion spring forces the outer string section to stop against a shoulder of the outer jacket such that the outer string section is pre-tensioned between the spring and the shoulder in such a manner that the torque combined with the axial force must exceed a predetermined value before relative movement between the inner and outer string sections will occur.

4. A dynamic damper installed in a drill string above a drill bit, the damper comprising:

an inner cylindrical string section having an upper end connected to an upper portion of the drill string;

an outer cylindrical string section supported concentrically on the inner string section and having a lower end connected to a lower portion of the drill string;

wherein the inner and outer string sections are engaged via a spiral trapezoidal threaded section oriented so that relative rotation between the string sections will cause relative axial movement between the string sections;

a spring disposed between the inner and outer string sections, the spring being pre-tensioned so that axial movement between the inner and outer string sections occurs only when combined axial force and torque on the sections exceed a predetermined value;

wherein the spring is a torsion spring that has one end stopped against the inner string section and another end stopped against the outer string section;

wherein torque caused by locking of the drill bit attached to the lower portion of the drill string effects relative rotation between the inner and outer string sections when said torque exceeds a selected spring tension;

wherein said relative motion between the inner and outer string sections is an axial movement that lifts and loosens the drill bit from the drill bit's locked position;

wherein said lifting and loosening of the drill bit reduces said torque such that the spring tension pushes the drill bit in a direction away from the damper.

5. The dynamic damper of claim **4**, comprising a cylindrical jacket arranged externally of the outer string section and connected to the inner string section such that the jacket protects the outer and inner string sections and constitutes a limitation for axial movement between the outer and inner string sections.

6. The dynamic damper of claim **4**, comprising two oil-filled volumes located between the inner and outer string sections and being connected such that relative axial movement of the inner and outer sections forces displacement of oil from one of the volumes to the other volume, thus dampening movement between the sections.

7. The dynamic damper of claim **5**, wherein the torsion spring forces the outer string section to stop against a shoulder of the cylindrical jacket such that the outer string section is pre-tensioned between the spring and the shoulder in such a manner that the torque combined with the axial force must exceed a predetermined value before relative movement between the inner and outer string sections will occur.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,578,360 B2
APPLICATION NO. : 10/548928
DATED : August 25, 2009
INVENTOR(S) : Per Olav Haughom

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page:

The first or sole Notice should read --

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 545 days.

Signed and Sealed this

Seventh Day of September, 2010

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office

EXHIBIT B – U.S. PATENT NO. 10,533,376

US010533376B2

(12) **United States Patent**
Reimers

(10) **Patent No.: US 10,533,376 B2**
(45) **Date of Patent: Jan. 14, 2020**

(54) **REGULATING DEVICE AND A METHOD OF USING SAME IN A BOREHOLE**

(71) Applicant: **Tomax AS**, Stavanger (NO)

(72) Inventor: **Nils Reimers**, Bjoa (NO)

(73) Assignee: **Tomax AS**, Stavanger (NO)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 203 days.

(21) Appl. No.: **15/524,671**

(22) PCT Filed: **Jan. 26, 2016**

(86) PCT No.: **PCT/NO2016/050009**

§ 371 (c)(1),
(2) Date: **May 5, 2017**

(87) PCT Pub. No.: **WO2016/122329**

PCT Pub. Date: **Aug. 4, 2016**

(65) **Prior Publication Data**

US 2017/0342781 A1 Nov. 30, 2017

(30) **Foreign Application Priority Data**

Jan. 29, 2015 (NO) 20150131

(51) **Int. Cl.**
E21B 4/10 (2006.01)
F16F 13/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***E21B 4/10*** (2013.01); ***E21B 17/073*** (2013.01); ***F16F 9/26*** (2013.01); ***F16F 13/00*** (2013.01)

(58) **Field of Classification Search**
CPC F16F 13/00; F16F 9/26; E21B 17/073; E21B 10/36; E21B 1/00; E21B 4/06; E21B 4/10
See application file for complete search history.

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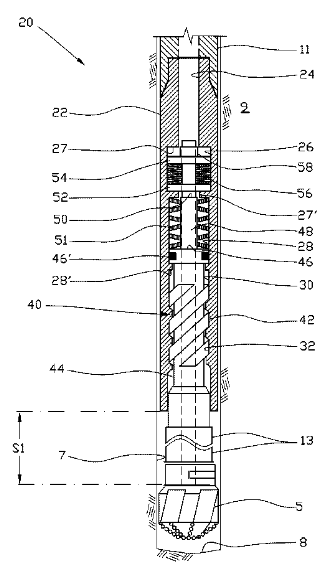
(Continued)

Primary Examiner — Brad Harcourt
(74) *Attorney, Agent, or Firm* — Andrus Intellectual Property Law, LLP

(57) **ABSTRACT**

A regulating device is for use in a drill string between a drilling machine and a drill bit. The regulating device has a tubular female portion which at least partly encloses a tubular male portion; a helical coupling between the female portion and the male portion to allow a telescoping movement of the regulating device in both directions between a fully extended position and a fully retracted position, the movement of the regulating device occurring when there is a difference in rotational speed between the female portion and the male portion; a first biasing device which is arranged to exert a driving force to drive the regulating device towards its extended position; and a second biasing device.

11 Claims, 5 Drawing Sheets



(51) **Int. Cl.**
F16F 9/26 (2006.01)
E21B 17/07 (2006.01)

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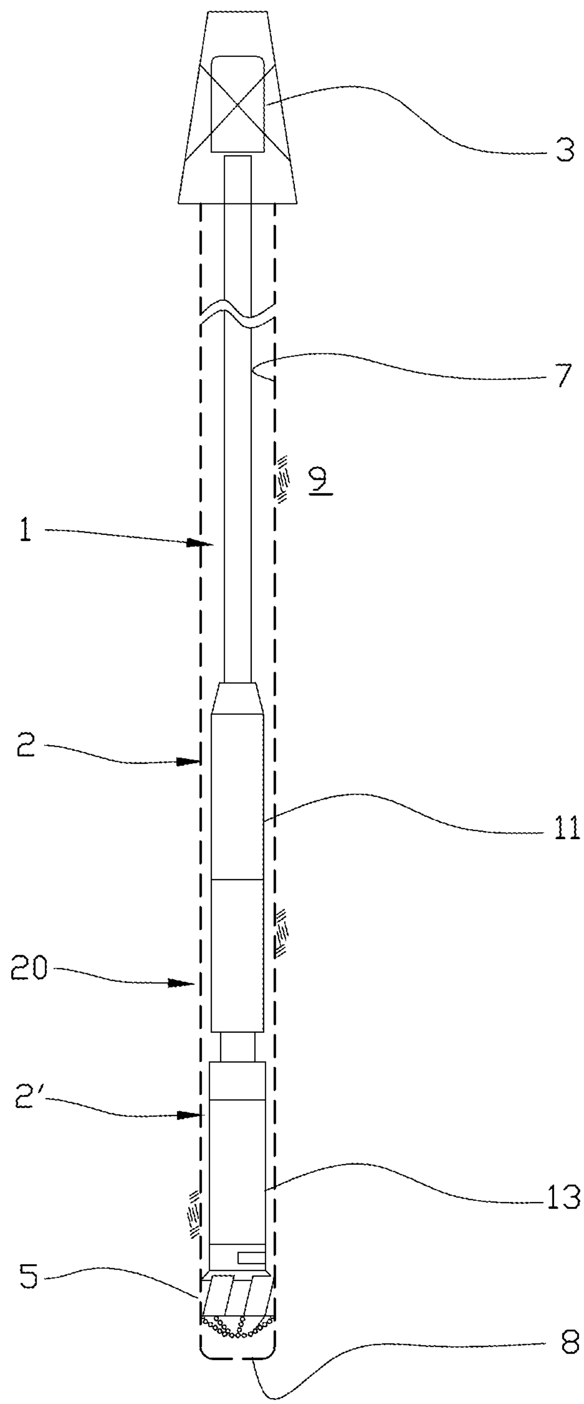

Fig. 1

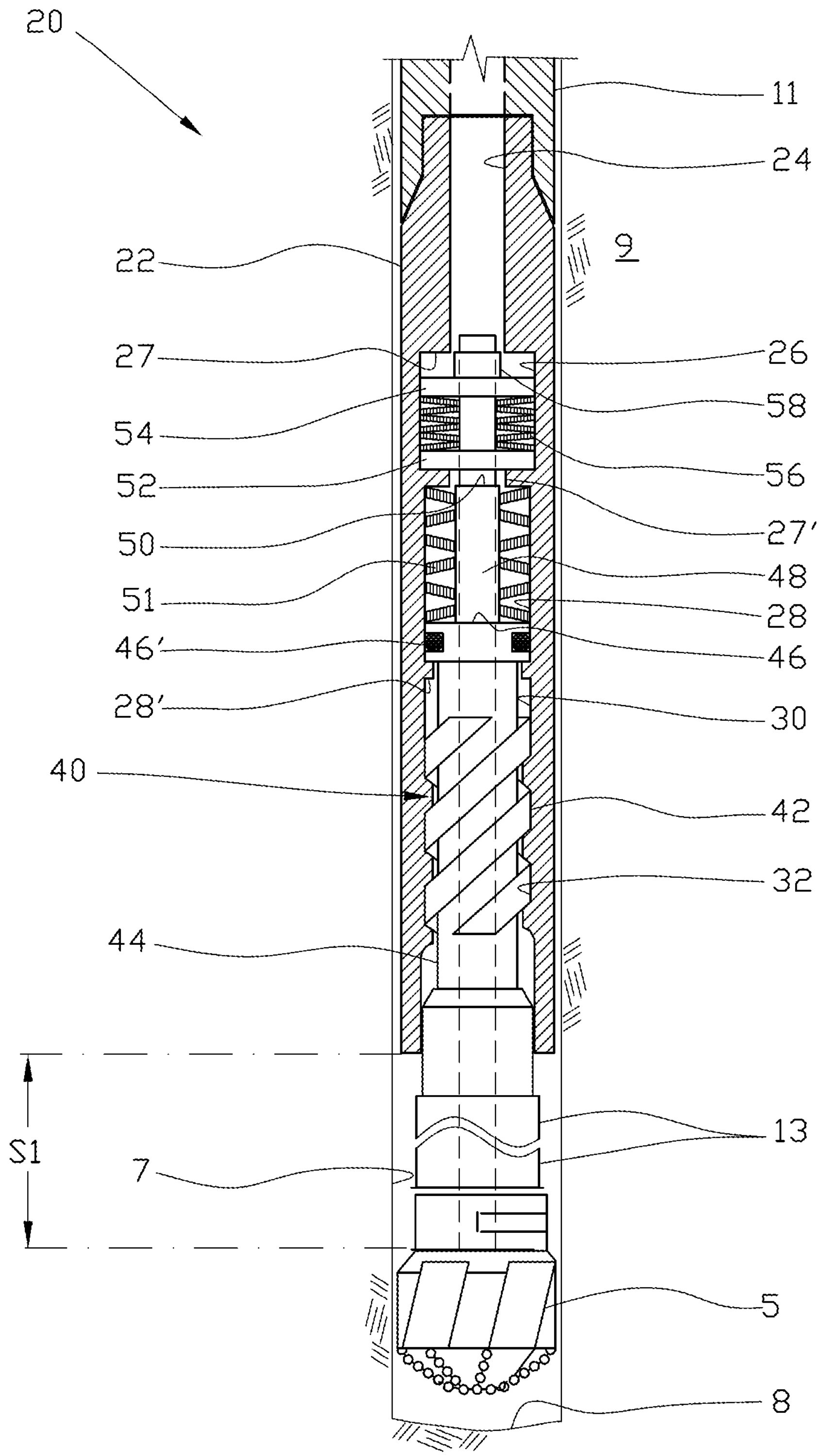
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Fig. 2

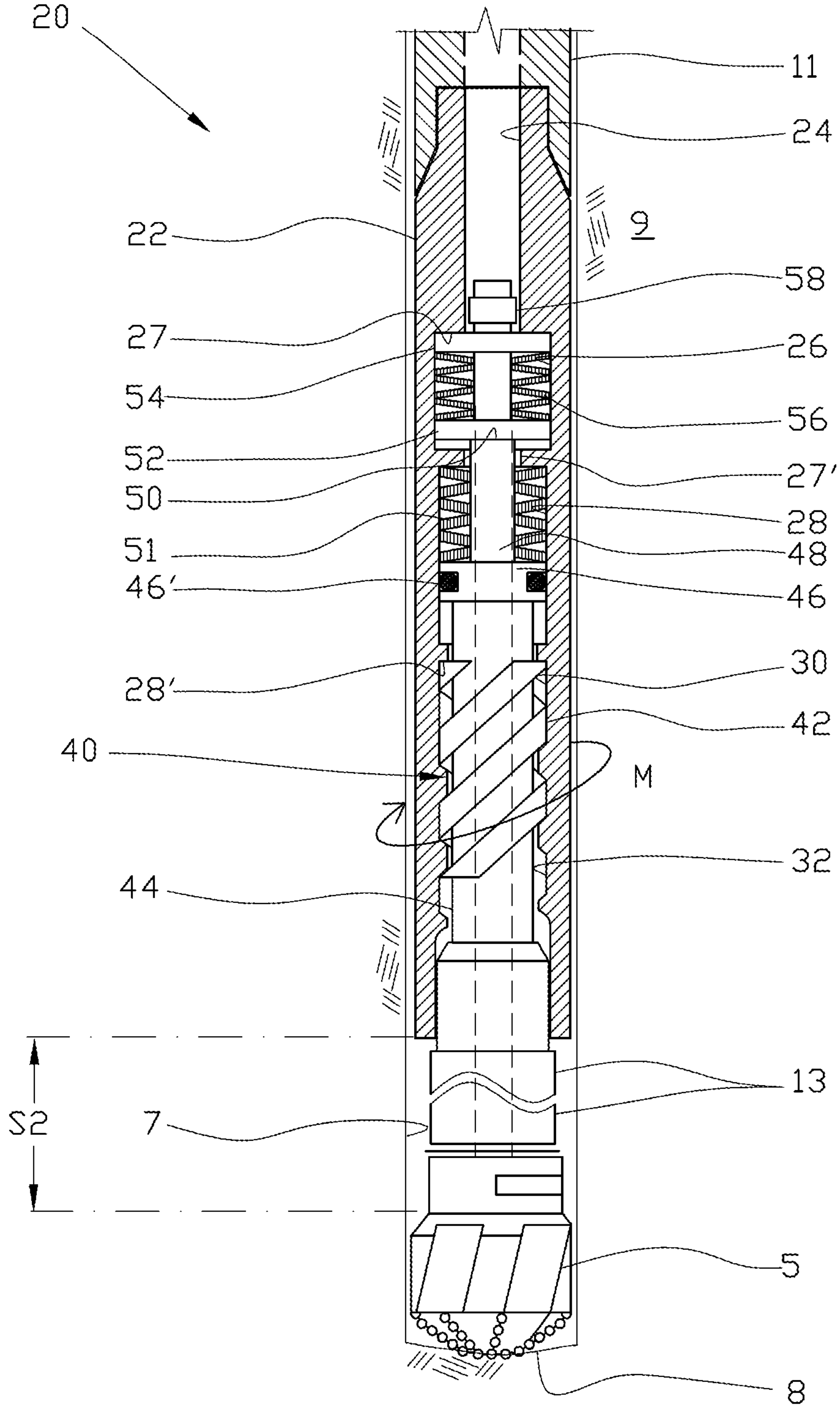
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Fig. 3

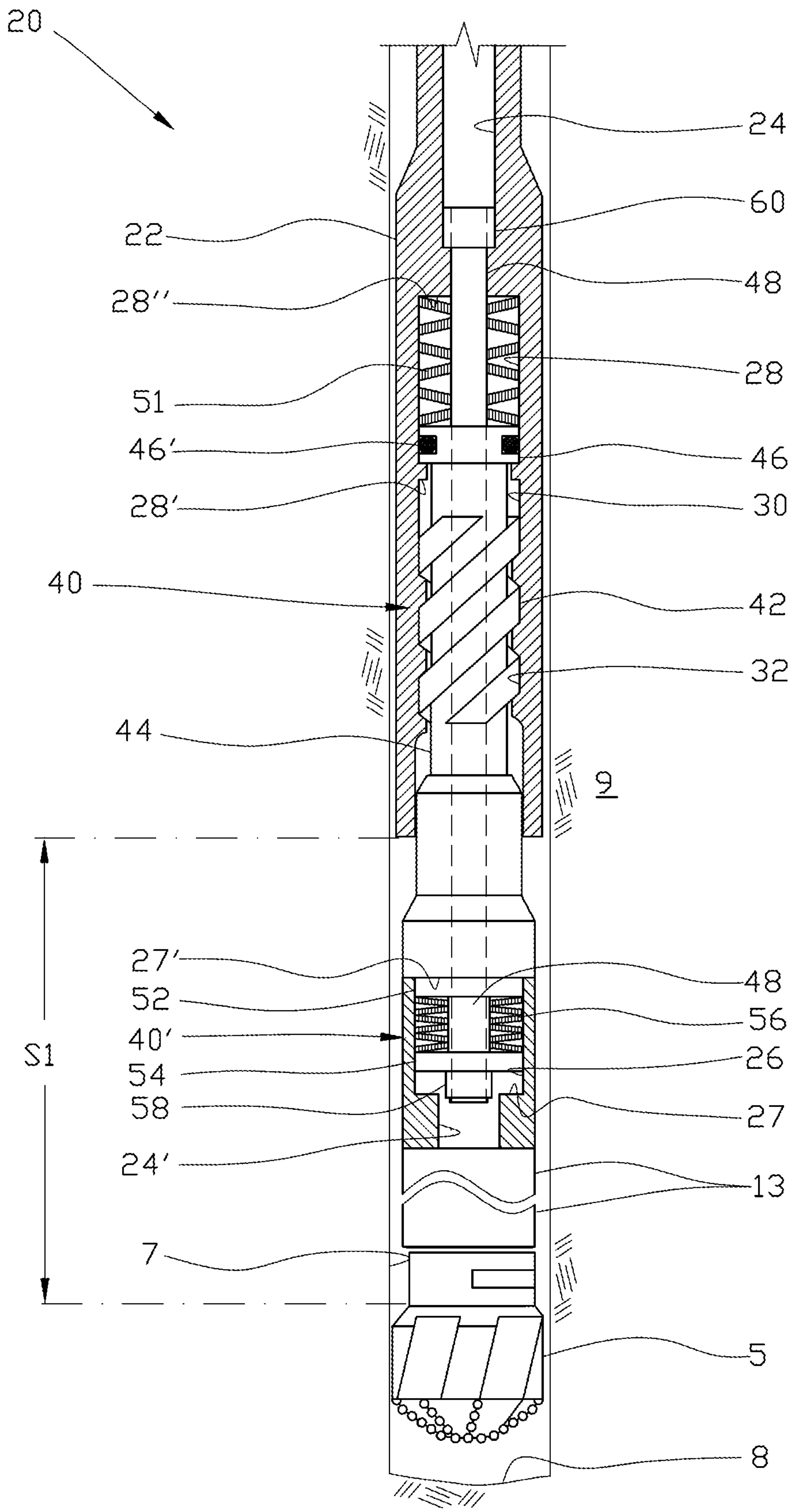

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Fig. 4

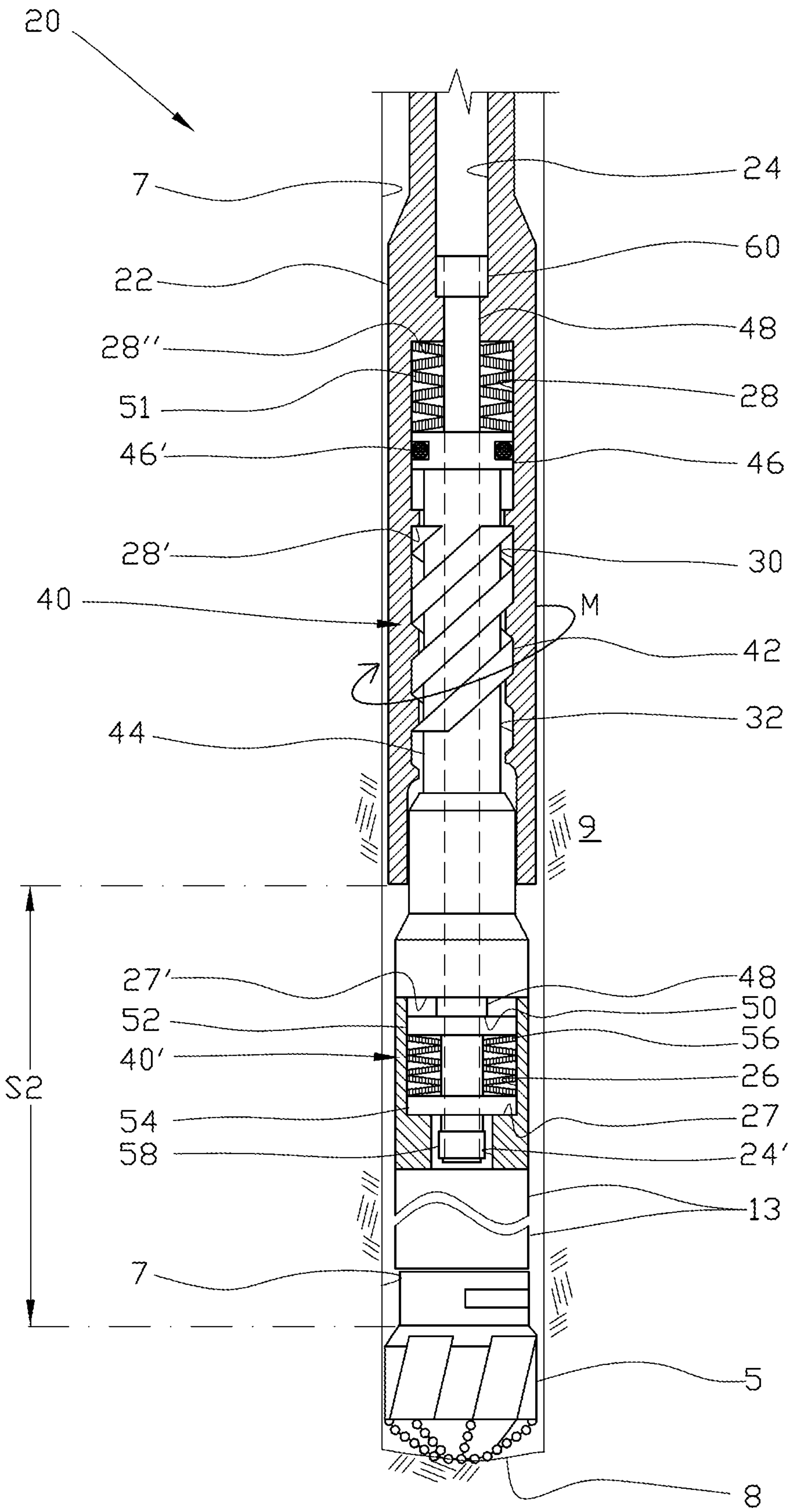
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Fig. 5

REGULATING DEVICE AND A METHOD OF USING SAME IN A BOREHOLE

FIELD

The present invention relates to a regulating device and a method of using the regulating device in a borehole in the ground. More particularly, it relates to a regulating device for use in a drill string between a drilling machine and a drill bit, the regulating device being configured to limit a reaction force against the drill bit when this is being fed in to establish a work surface at the bottom of the borehole or hits rocks or formations of different characteristics.

BACKGROUND

To reduce the risk of damage to the drill bit in consequence of limited control of the exact position of and strain on the drill bit in deep boreholes, it is known to use solutions pertaining to the design of the drill bit itself. Some of the solutions aim at making the drill bit less aggressive and thereby less sensitive when meeting a work surface against which the drill bit is brought. An example of one such solution used is the reduction of a so-called angle of attack of the cutting elements of the drill bit, so that less reactive force is produced in relation to weight-on-bit. Weight-on-bit is a known term in the drilling industry and relates to the axial force exerted by the drill bit against the work surface. With reduced reactive force, a lower risk of vibrations in the radial direction of the drill bit is achieved. In the specialist environment, such vibrations are known as "stick-slip" which is a stop-and-start motion or "jerking". The same object is sought to be achieved by producing the cutting elements of the drill bit with a bevel instead of a straight cutter angle.

Generally, the drawback of such solutions is that a considerable increase in weight-on-bit is required when the cutters are to establish engagement in hard rock. Such an increased weight-on-bit is exponentially reflected in increased frictional heat in the cutting elements of the drill bit, which constitutes a technological barrier; the cutting elements that are used in a drill bit for drilling a subsea formation or a rock on land, are made, in the main, from polycrystalline or synthetic diamond in which the diamond fragments are bonded together into circular plates by the use of cobalt. This material combination is sensitive to heat, and the strength is reduced exponentially from 350° C. In reality, said increased frictional heat in the cutting elements of the drill bit causes existing solutions, with protection of the drill bit when being fed in, to be incompatible with drilling in bedrock, for example. This is a considerable barrier to economic utilization of geothermal heat and deep oil and gas deposits.

Consequently, optimum utilization of such sharp, energy-efficient cutting elements that are necessary for cutting hard rock without overheating must be based on principles other than reduced angle of attack and increased supporting surface. The prior art is common, axial shock absorbers for a drill string. Such shock absorbers went through a rapid development in the period from around 1960 to around 1980 and gained considerable ground together with roller bits.

From this period, the following publications are known: U.S. Pat. Nos. 3,073,134, 3,225,566, 3,329,221, 3,382,936, 3,947,008, 3,963,228, 4,054,040, 4,133,516, 4,162,619, 4,173,130, 4,186,569, 4,194,582, 4,210,316, 4,211,290, 4,257,245, 4,303,138, 4,398,898, 3,871,193 and 4,901,806.

Out of the above-mentioned publications, the publication U.S. Pat. No. 4,186,569 is particularly interesting, as it discloses an axial shock absorber to be built into a drill string with the object of preventing axial vibrations and shocks during drilling. The object is achieved by using a telescopic unit with straight, axial splines to transmit torque, the unit being kept extended by means of springs. Oil is used as the damping medium in accordance with a known principle. Of particular interest in this device is a separate counterspring, the purpose of which is to balance the force from internal pressure and stretching from the gravitational force acting from the part of the drill string that is arranged below the unit in the direction of the drill bit when the drill bit is free, above the bottom, that is, or has low weight-on-bit.

However, axial shock absorbers were phased out with the introduction of drill bits with shearing cutters as these have insignificant vibration challenges in the axial direction, but all the more risk from impacts or jerking in the radial direction. Such impacts or jerking may occur especially when the drill bit is being fed into the borehole and at transition zones between rocks or formations of different characters, typically at the transition from one rock to a subsequent harder rock.

From the publication US 20140090892, an apparatus for maintaining so-called "weight-on-bit", or "thrust" which is the axial force exerted by the drill bit against the work surface during a drilling operation, is known. The apparatus is a rotationally rigid damping device arranged to damp axial vibrations in a drill string.

A more suited solution for reducing said impacts or jerking is a torque converter of the kind that transforms undesired impacts and "peaks" in the torque into a mechanically controlled axial motion which proportionally relieves the drill bit. However, this solution requires rigid internal compression springs. This rigidity makes the torque converter give little or no protection at low strains, for example in the engagement phase. That is to say, as the drill bit is brought into engagement with a rock.

The latter mechanical torque converters for drill strings were developed somewhat later than axial shock absorbers for drill bits. Such mechanical torque converters are known from the publications U.S. Pat. No. 7,044,240 and NO 315209.

Said publications NO 315209 and U.S. Pat. No. 7,044,240 disclose torque converters for building into a drill string with the object of preventing overload from torque variation during drilling. The object is achieved by using a telescopic unit with an internal, steep thread coupling, wherein the unit is kept extended or expanded by means of great cooperating forces provided by means of a compression spring and internal fluid pressure and the gravitational force acting on the part of the drill string that is arranged below the unit, in the direction of the drill bit, that is. Undesired impacts and torque peaks are converted through the threaded coupling into an axial contraction proportionally relieving the drill bit. The expansion forces mentioned above have as their purpose to restore the axial force on the drill bit as soon as the torque load decreases. A person skilled in the art will know that such expansion forces must be large. However, large expansion forces have the disadvantageous effect of the torque converter being fully extended and in practice rigid during feeding against the work surface. Consequently, the solutions that are disclosed in NO 315209 and U.S. Pat. No. 7,044,240 have a very limited effect before the drill bit has become fully engaged. This means that in cases in which the work surface is uneven, the drill bit may be damaged before the torque converter gets into function. To reduce or

avoid said disadvantageous effect, tests have been performed with a reduction in the expansion forces acting on the drill bit, to bring the torque converter into function at a lower load, accordingly to provide a more "sensitive" torque converter. However, said tests have shown that such a more "sensitive" torque converter gives a reduced capacity during normal operation, drilling, that is.

From the publication US 2014262650, an apparatus for damping torsional oscillations to which a drill string may become subjected in a well, is known. The apparatus is axially rigid.

SUMMARY

The invention has for its object to remedy or reduce at least one of the drawbacks of the prior art, or at least provide a useful alternative to the prior art.

The object is achieved through the features which are given in the description below and in the claims that follow.

A regulating device according to the present invention is a development of features known from axial shock absorbers for drill strings and features from mechanical torque converters for drill strings.

The regulating device according to the invention enables both safe feeding and drilling with fixed, sharp cutters in hard rock. This is achieved by the regulating device being arranged in the lower part of the drill string, accordingly in the direction of the drill bit. The regulating device includes features from the torque converters according to NO 315209 and U.S. Pat. No. 7,044,240, but the solutions of the torque converters for the springs have been replaced with a balanced principle which has its starting point in, but is a development of, earlier axial shock absorbers.

The invention is defined by the independent claims. The dependent claims define advantageous embodiments of the invention.

In a first aspect of the present invention, a regulating device for use in a drill string between a drilling machine and a drill bit is provided, the regulating device comprising:

- a tubular female portion which at least partly surrounds a tubular male portion;
- a helical coupling between the female portion and the male portion to allow a telescoping movement of the regulating device in both directions between an extended position and a retracted position, said movement by the regulating device occurring when there is a difference in rotational speed between the female portion and the male portion;
- a first biasing device which is arranged to exert a driving force to drive the regulating device towards its extended position; and
- a second biasing device.

The regulating device in the second biasing device has an associated driving device whose axial position in the regulating device is controlled by mutual axial position of the male portion and the female portion by a portion of the driving device being axially connected to the male portion, that the male portion is subjected, via the driving device, to a force from the second biasing device, the force being opposite to the driving force from the first biasing device when the regulating device is in its extended position, and that the male portion is subjected, via the driving device, to a force from the second biasing device which is co-directional with the driving force from the first biasing device when the regulating device is in its retracted position, the second biasing device being axially displaceable in a second chamber which is axially defined by a shoulder and a ledge, the displacement of the second biasing device between said shoulder and said ledge being smaller than the telescoping movement of the male portion between the fully extended position and the fully retracted position.

The effect of this is that when the drill bit is off the bottom and the regulating device is in its fully extended position, the resistance to relative rotation between the male portion and the female portion will be smaller than when the regulating device is near its fully retracted position. Thus, the drill bit which is connected to the regulating device will be more "sensitive" when the regulating device is in its fully extended position, which is typically when the work surface is being established, than when the regulating device is near its most retracted or contracted position. When the regulating device is in its most contracted position and the weight-on-bit is maintained during the drilling operation, relative rotation of the male portion and the female portion cannot occur.

The second biasing device may be arranged to substantially balance the forces that are extending the regulating device into its extended position, when the regulating device is in its fully extended position. The forces extending the regulating device are said first biasing device and the gravitational force from the major part of the mass of the male portion.

The effect of this is that when the drill bit is off the bottom, said second biasing device will balance the considerable forces extending the regulating device into its fully extended position. With respect to the thrust on the drill bit, the male portion of the regulating device will appear almost "weightless". Thereby the friction in the helical coupling between the male portion and the female portion will also be the smallest one possible, which is favourable with a view to providing a regulating device which is very sensitive when in its most extended position.

When the drill bit meets the work surface at the bottom of the hole, the second biasing device will gradually be relieved in consequence of the regulating device contracting.

Thus, according to the present invention, a continued contraction of the regulating device will cause the second biasing device to be compressed together with the first biasing device of the regulating device. In this way, an increase in maximum biasing force is achieved, compared with the prior art. In sum, the invention gives an interval with the least possible risk of damage when the drill bit meets the contact surface. In the next place, a considerably improved maximum power capacity in the drilling phase is achieved. The regulating device according to the invention thereby gives improved protection and more reliable use of the optimized, sharp cutters mentioned initially, which are necessary for drilling in hard rock, while, at the same time, the total capacity will be higher. A person skilled in the art will know that in the same way as sharp cutters are necessary for cutting hard metal, sharp cutters are also a condition for drilling hard rock.

The first biasing device is preferably arranged in a first chamber in a portion of the female portion, the volume of the chamber being controlled by a piston associated with the male portion. Thereby the compression of the first biasing device is dependent on the axial position of the male portion relative to the female portion.

The driving device may include a first pressure plate and a second pressure plate which are individually movable in the second chamber, where the pressure plates are kept spaced apart by the second biasing device, and where the movements are controlled by a rod connected to said piston

associated with the male portion. In one embodiment, the axial extent of the chamber is larger than the extent of the driving device.

In one embodiment, the second chamber is arranged in a portion of the female portion. In an alternative embodiment, the second chamber is arranged in a portion of the male portion.

Preferably, at least one of the biasing devices comprises a spring. Each of the at least one spring may be selected from the group: a helical spring or a series of disc springs. In the present invention, a series of disc springs is particularly well suited.

One of the advantages of using a spring as the biasing element instead of a biasing element based exclusively on a compressible fluid is that a spring may have a more predictable characteristic, thus be less susceptible to influence from, among other things, the temperature conditions prevailing in a petroleum well, for example. Besides, a compressible fluid would have to be placed in a closed chamber, which involves the use of seals with associated wear and friction problems. Accordingly, a spring is a technically simpler solution and appears, for the time being, to be the best solution for the field of application in question. But it should be emphasized that it is also conceivable to use fluid-based biasing elements as described below. This is because a fluid-based biasing element has advantages related to easy change of the fluid pressure and thereby adaptation of the power characteristics of the biasing element for specific drilling jobs.

In one embodiment, the first biasing device may further include a fluid under pressure. The biasing device may thus include both a spring and a fluid, as will be explained in connection with the exemplary embodiment below.

In a second aspect of the present invention, a method of controlling the weight-on-bit connected to a drilling machine via a drill string is provided, the method comprising: positioning a regulating device according to the first aspect of the invention in the drill string between the drilling machine and the drill bit; and running the drill string into and setting the drill string and drill bit in rotation in the borehole; and bringing the drill bit into engagement with a bottom portion of the borehole.

The method may further comprise arranging the regulating device between two drill collars which are integrated in a lower portion of the drill string near the drill bit.

The second biasing device may be arranged with such a power capacity that when the regulating device is in its most extended position, the second biasing device is arranged to balance the sum of the force from the first biasing device and a vertical component of the gravity of the mass of the components included in the lower drill-string portion.

BRIEF DESCRIPTION OF THE DRAWINGS

In what follows, examples of preferred embodiments are described, which are visualized in the accompanying drawings, in which:

FIG. **1** shows a principle drawing of a drill string extending from a top-drive drilling machine to a drill bit which is near a bottom portion in a well, there being a regulating device according to the present invention arranged between two drill collars in a lower portion of the well;

FIG. **2** shows a view on a larger scale, partially in perspective, of the regulating device which includes a female portion partially enclosing a male portion, the regulating device being in an extended position which it will have when the drill bit is at a distance from the bottom portion of the well, among other things;

FIG. **3** shows the regulating device of FIG. **2**, but the regulating device is in a retracted position in consequence of the drill bit having been brought into engagement with the bottom portion of the well;

FIG. **4** shows an alternative embodiment of the regulating device shown in FIG. **2**; and

FIG. **5** shows the regulating device of FIG. **4** in a retracted position.

DETAILED DESCRIPTION OF THE DRAWINGS

In what follows, positional indications like “above”, “below”, “upper” and “lower” refer to the positions that the individual elements have in the figures.

Like or corresponding elements are indicated by the same reference numeral.

In the figures, the reference numeral **1** indicates a drill string which extends from a top-drive drilling machine **3**, or just “top drive”, to a drill bit **5**. For a well on land, the drilling machine **3** may be arranged on a fixed or mobile drilling rig. For a subsea well, the drilling machine **3** will be arranged on a floating vessel.

By means of the drilling machine **3**, the drill string **1** and thereby the drill bit **5** are arranged to be set in rotation around their longitudinal axis, as will be known to a person skilled in the art.

FIG. **1** shows, in principle, the drill string **1** and drill bit **5** after they have been run into a borehole **7** in a formation **9**. The drill bit **5** is near a bottom portion **8** of the borehole **7**. The borehole **7** will in what follows also be denoted well **7** or wellbore **7**.

In the embodiment shown, the drill string **1** is provided with a first drill collar **11** and a second drill collar **13** of a kind known per se. The drill collars **11**, **13** are integratedly arranged in a lower portion of the drill string **1** near the drill bit **5**. A person skilled in the art will know that drill collars **11**, **13** are used to provide weight-on-bit on the drill bit **5**.

A regulating device **20** according to the present invention is arranged between the first drill collar **11** and the second drill collar **13**, as shown in principle in FIG. **1**. The purpose of the regulating device **20** is to limit or damp so-called jerking or “stick-slip” which may occur as the drill bit **5** engages a portion of the borehole **7**, **8**, or a transition zone as explained below.

In what follows, to facilitate the understanding of the invention, the drill string **1** has been divided into an upper drill-string portion **2** and a lower drill-string portion **2'**.

The upper drill-string portion **2** comprises the portion of the drill string **1** which extends from the drilling machine **3**, via the first drill collar **11** to (including) a female portion of the regulating device **20**.

The lower drill-string portion **2'** comprises the portion of the drill string **1** that comprises a male portion **40** of the regulating device **20**, the second drill collar **13** and the drill bit **5**. In what follows, the male portion will also be referred to as a telescoping device **40**.

FIGS. **2-5** show the drill bit **5**, the second drill collar **13** (shown shortened) and the regulating device **20** on a larger scale. For the sake of simplicity, the first drill collar **11** is shown only in FIGS. **2-3**.

FIGS. **2** and **3** show a first embodiment of the present invention, whereas FIGS. **4** and **5** show a second embodiment of the present invention.

The regulating device **20** includes said female portion which is referred to as a housing **22** (shown in section) in

what follows. The housing **22** is thus fixedly connected to the first drill collar **11** and forms part of the upper drill-string portion **2**.

The housing **22** can be split along its longitudinal axis and includes two semicircular elements which are attached to each other by means of mechanical attachment means known per se.

The housing **22** encloses a portion of the male portion or the telescoping device **40**. The telescoping device **40** is fixedly connected at its lower end portion to the drill bit **5** via the second drill collar **13**. The telescoping device **40**, the second drill collar **13** and the drill bit thus constitute the lower drill-string portion **2'**.

The lower drill-string portion **2'** is configured for a limited axial and rotational movement relative to the upper drill-string portion **2**.

Reference is first made to the embodiment according to FIGS. **2** and **3**.

The housing **22** is provided with four chambers: a fluid channel **24** for the supply of drilling fluid to the drill bit **5**, a second chamber **26**, a first chamber **28** and a rotation chamber **30**. The fluid channel **24** is in fluid communication with the second chamber **26** and the first chamber **28** and with the drill bit **5** through a channel (shown in broken lines) through the regulating device **20**.

The first chamber **28** is defined by a first ledge **27'** which extends radially inwards from the jacket portion of the housing **22**, the jacket portion of the housing **22** and a second ledge **28'** which extends radially inwards from the jacket portion of the housing **22**.

The second chamber **26** is defined by a shoulder **27**, said first ledge **27'** and the jacket portion of the housing **22**.

The rotation chamber **30** is defined by said second ledge **28'**, the jacket portion of the housing **22** and the lower end portion of the housing **22**.

The rotation chamber **30** is provided with a helical guide **32**. The guide **32** is complementarily adapted to a helical thread **42** arranged on a stem **44** of the telescoping device **40** which is in the rotation chamber **30**. As shown in the figures, the axial extent of the thread **42** is smaller than the axial extent of the rotation chamber **30**. The stem **44** may thus be screwed in the housing **22** from the position shown in FIG. **2** to the position shown in FIG. **3**, in which an upper end portion of the helical thread **42** has been brought into abutment against the second ledge **28'**.

The telescoping device **40** further includes a piston **46** which is attached to an upper end portion of the stem **44**. The piston **46** is further attached to a pipe **48** which extends axially through the first chamber **28** and the second chamber **26**. In an upper end portion of the first chamber **28**, the pipe **48** is provided with an external shoulder **50**. The piston **46** is arranged to be axially movable and rotatable relative to the housing **22**.

The piston **46** is provided with a sealing element in the form of an annular seal **46'** to prevent drilling fluid from flowing from the first chamber **28** into the rotation chamber **30** and thereby leaking into the borehole **7**.

The drill collar **13**, the stem **44** and the pipe **48** are provided with a through channel (indicated in broken lines) to allow fluid communication between the fluid channel **24** and the drill bit **5**. The pipe **48** is connected to a bore in the stem **44**.

A biasing device in the form of a spring **51** is arranged in the first chamber **28** around the pipe **48** between the piston **46** and the ledge **27'**. In what follows, the spring **51** will also be referred to as the main spring **51**. In the embodiment shown, the biasing device also includes a fluid acting on the piston **46**. The fluid acting against the piston **46** is in fluid communication, via the second chamber **26**, with the fluid channel **24**.

In the second chamber **26**, a first pressure plate **52** is kept at a distance from a second pressure plate **54** by means of a biasing device in the form of a spring **56** which is also called a counterspring **56** in what follows. The pressure plates **52**, **54** are axially and rotatably movable relative to the pipe **48**. The pressure plates **52**, **54** may alternatively or additionally be rotatable relative to the housing **22**.

The springs **51**, **56** are of a kind known per se and may typically be a series of disc springs or helical springs depending on the desired characteristics of the spring. In a prototype of the regulating device **20** according to the invention, a series of disc springs have been used, which turns out to function in a very satisfactory manner.

The axial movement of the pressure plates **52**, **54** in the second chamber **26** is restricted by the ledge **27'** and shoulder **27**, respectively, and a stopping device **58** securely attached, for example by means of a threaded connection, to an upper end portion of the pipe **48**.

From the description above, it will be understood that the telescoping device **40** is arranged to allow a limited rotation to be applied to it relative to the housing **22**. The limitation is controlled by the axial position of the helical thread **42** in the rotation chamber **30**.

In FIG. **2**, the drill bit **5** is near, but at a distance from, a bottom portion **8** of the borehole **7**. The drill bit **5** is in a "non-strained" position. In this position, the gravity of the mass of the telescoping device **40**, the second drill collar **13** and the drill bit **5**, that is to say the lower drill-string portion **2'**, and the force from the main spring **51** and the fluid pressure from the fluid acting against the upper portion of the piston **46**, are balanced by an opposite force transmitted from the pipe **48** via the stopping device **58** to the second pressure plate **54**, and from the second pressure plate **54** via the counterspring **56**, the first pressure plate **52** to the first ledge **27'** of the housing **22**.

In this non-strained position, the male portion **40** will almost "float" relative to the female portion **22**. This has the positive effect of the friction in the helical coupling **32**, **42** being at a minimum. This further contributes to a reduced threshold value as will be discussed below.

By the very fact of the forces being balanced in the position shown, the stress between the bottom face of the piston **46** and the second ledge **28'** will be close to zero.

In FIG. **2**, the main spring **51** is in its most relieved position in the first chamber **28**, whereas the counterspring **56** in the second chamber **26** is in its most compressed position. Consequently, the distance S1 between the lower end portion of the housing **22** and the drill bit **5** is the largest possible.

The regulating device **20** according to the invention is configured in such a way that undue compression of the counterspring **56** is prevented by the downward axial movement of the piston **46** being restricted by the second ledge **28'**.

In FIG. **3**, the drill bit **5** has been brought into engagement with the bottom portion **8** of the borehole **7**. On the occurrence of such contact, the rotational speed of the drill bit **5** may be reduced in consequence of the friction that arises between the drill bit **5** and the bottom portion **8**. By such a difference in rotational speed between the upper drill-string portion **2** and the lower drill-string portion **2'**, the thread **42** of the stem **44** will be screwed along the helical guide **32** of the housing **22** from the position that is shown in FIG. **2**, until the upper end portion of the thread **42** is brought into

abutment against the second ledge **28'** as shown in FIG. **3**. As such an axial motion between the housing **22** and the telescoping device **40** occurs in consequence of said rotational motion between the telescoping device **40** and the housing **22**, the piston **46** will be moved upwards together with the piston **48** in the first chamber **28**, and the main spring **51** will be compressed while, at the same time, the counterspring **56** is relieved and consequently is allowed to expand until the second pressure plate **54** has been brought into abutment against the shoulder **27** in the second chamber **26**. When the compression of the main spring **51** continues, the external shoulder **50** of the pipe **48** will be brought into abutment against the first pressure plate **52** and through this compress the counterspring **56** against the second pressure plate **54** which in turn has been brought into abutment against the shoulder **27** in the upper end portion of the chamber **26**. As mentioned, the pressure plates **52**, **54** run freely on the pipe **48**, but are prevented from moving in the axial direction beyond the stopping device **58**, the shoulder **27** and the first ledge **27'**. Accordingly, a further compression of the main spring **51** will involve or require concurrent compression of the counterspring **56**.

The regulating device **20** is configured in such a way that before the upper end portion of the thread **42** has been brought into abutment against the second ledge **28'**, the shoulder **50** of the pipe **48** will be brought into abutment against a lower end face of the first pressure plate **52** and push this upwards in the first chamber **26**. Consequently, the counterspring **56** will also be compressed and, together with the main spring **51** and the force from the fluid acting on the piston **46** in the first chamber **28**, exert resistance to a further, last upward movement of the telescoping device **40**. Accordingly, the counterspring **56**, too, will exert a pressure on the drill bit **5**.

Torque M occurring between the housing **22** and the telescoping device **40** as mentioned above, will lead to a reduction of the length S**1**. The reduction of the length S**1** is counteracted by the main spring **51**, the force from the fluid acting against the upper face of the piston **46** and the gravity from the mass of the drill collar **13** and the drill bit **5**. Without the arrangement with the counterspring **56**, the torque M required in order to balance the force from the fluid acting against the piston **46** and from the mass below the telescoping device **40** might constitute an unfavourable threshold value in relation to the range of action of the regulating device **20**. However, as mentioned, the arrangement with the counterspring **56** balances said forces so that the reduction of the length from the length S**1** shown in FIG. **2** to the length S**2** in FIG. **3**, happens relatively immediately, and then substantially without a threshold value, the moment the drill bit **5** is brought against the bottom portion **8** of the borehole **7**, for example.

To sum up the above, it will thus be understood that as the piston **46** is driven upwards in the housing **22**, the main spring **51** will be compressed. Concurrently with the occurrence of such a compression of the main spring **51**, the counterspring **56** will be relieved. Accordingly, a constantly larger portion of the gravity of the mass of the telescoping device **40**, the second drill collar **13** and the drill bit **5**, that is to say the lower drill-string portion **2'**, will act against a further upward movement of the telescoping device **40**.

In cases in which the strain on the drill bit **5** is great and the regulating device **20** is approaching its most retracted position as shown in FIG. **3**, the counterspring **56** will be compressed again, as mentioned, but now in such a way that the force from the counterspring **56** acts in the same direction as the force from the main spring **51**, the force from the fluid acting against the piston **46** and the gravitational forces from the telescoping device **40**, the second drill collar **13** and the drill bit **5**.

As shown in the exemplary embodiments, the helical coupling **32**, **42** that transmits and converts torsional load separate from the springs **51**, **56**, runs in relation to the torque load, transmitting a codirectional axial load to and from the springs through the driving device which comprises the pipe **48**. This has the effect of allowing the pipe **48**, which is a central spring guide bushing, to be formed with the smallest possible outer diameter. Thereby, the series of disc springs may be formed with optimum dimensions, and without the use of disc springs arranged in parallel series, such as so-called double-packing or triple-packing which has to be used in some cases to achieve sufficient strength. A person skilled in the art will know that such a double- or triple-packing could generate increased internal friction and consequently a reduced overall efficiency and operational predictability.

In a prototype of the present invention, disc springs with a ratio of sizes of the external diameter to the internal diameter of approximately 1.95 are used, which is considered ideal in relation to recommended boundary values which are in the range of 2.45-1.76 for the relevant spring. The utilized ratio of sizes mentioned gives the disc springs their best possible properties in relation to operational stability, efficiency and length of life.

An important quality of the present invention is thus a quicker response, substantially without said threshold value and, at the same time, a considerable increase in the maximum load during drilling.

It should be noted that said “non-strained” position could also be the position that the drill bit **5** has when drilling through a uniform formation. But when penetrating an underlying formation of a different character that exerts greater friction or resistance to the progress of the drill bit **5**, the effect could be the same as that shown in the exemplary embodiments. Said bottom portion **8** is thus to be understood as possibly being a transitional portion from a first formation to a second formation, where said second formation offers greater resistance to the rotation or progress of the drill bit **5**.

Correspondingly, said bottom portion **8** could alternatively be the beginning of a sidetrack.

FIGS. **4** and **5** show an alternative embodiment of the apparatus shown in FIGS. **2** and **3**.

The embodiment shown in FIGS. **4** and **5** bear several similarities to the embodiment shown in FIGS. **2** and **3**. The main difference is that in FIGS. **4** and **5**, the second chamber **26** is arranged in a lower portion **40'** of the telescoping device **40** and not in a portion of the housing **22** as shown in FIGS. **2** and **3**. The housing **22** of FIGS. **4** and **5** is thus provided with three chambers: a rotation chamber **30**, a first chamber **28** and a fluid channel **24**. The fluid channel **24** is in fluid communication with the first chamber **28** as explained below.

In what follows, some of the elements that are mentioned and that have designs or functions corresponding to those of the elements that have already been described in the discussion of FIGS. **2** and **3** will be mentioned in the definite form without having been specifically mentioned earlier in relation to FIGS. **4** and **5**.

The first chamber **28** is defined by a shoulder **28"**, the jacket portion of the housing **22** and a second ledge **28'** which extends radially inwards from the jacket portion of the housing **22**.

The rotation chamber **30** is defined by said second ledge, **28'**, the jacket portion of the housing **22** and the lower end portion of the housing **22**.

The first chamber **28** and the rotation chamber **30** shown in FIGS. **4** and **5** thus have a design substantially corresponding to the design shown in FIGS. **2** and **3**. The same applies to the stem **44** with helical thread **42** arranged in the rotation chamber **30**. The description of these will therefore not be repeated.

In FIGS. **4** and **5**, a pipe **48** extends from the fluid channel **24** in the upper portion of the housing **22**, via a bore in the stem **44** of the telescoping device **40** to a lower fluid channel **24'** connected to the drill bit **5**. The pipe **48** is provided with a through bore.

In FIGS. **4** and **5**, the pipe **48** is terminated in an anchoring **60** attached to a portion of the fluid channel **24** in the housing **22** by means of attachment means (not shown) known per se, such as a threaded connection, bolts and/or latch pins. A lower portion of the pipe **48** has an associated stopping device **58** of the same kind as that shown in FIGS. **2** and **3**.

In the embodiment shown, the piston **46** and the stem **44** are rotatable and axially displaceable relative to the pipe **48**.

In the second chamber **26** arranged in the lower portion **40'** of the telescoping device **40**, a first pressure plate **52** is kept at a distance from a second pressure plate **54** by means of a biasing device in the form of a spring **56** which is also called a counterspring **56** in what follows. The counterspring **56** may be a series of disc springs. The pressure plates **52**, **54** are axially and rotatably movable relative to the pipe **48**. The pressure plates **52**, **54** may alternatively or additionally be rotatable relative to the housing **22**.

The axial movement of the pressure plates **52**, **54** in the second chamber **26** shown in FIGS. **4** and **5** is defined by a rim portion **27'** (corresponding to the ledge **27'** in FIGS. **2** and **3**) and a shoulder **27** and the stopping device **58** securely attached, for example by means of a threaded connection, to the lower portion of the pipe **48**.

In FIG. **4**, the drill bit **5** is in a "non-strained" position corresponding to that shown in FIG. **2**. In this position, the gravitational force from the mass of the telescoping device **40**, the second drill collar **13** and the drill bit **5** and the force from the main spring **51** and the fluid pressure acting against the upper portion of the piston **46** are balanced by an opposite force which is transmitted from the pipe **48** via the stopping device **58** to the second pressure plate **54**. From the second pressure plate **54**, the force path extends via the counterspring **56**, the first pressure plate **52** to the rim portion **27'** in the lower portion **40'** of the telescoping device **40**.

By the very fact of the forces being balanced in the position shown, the stress between the bottom face of the piston **46** and the second ledge **28'** is close to zero.

In a manner corresponding to that shown in FIGS. **2** and **3**, the regulating device **20** in the embodiment shown in FIGS. **4** and **5** is configured in such a way that too great a compression of the counterspring **56** is prevented by the downward axial movement of the piston **46** being restricted by the second ledge **28'**.

In FIG. **5**, the drill bit **5** has been brought into engagement with the bottom portion **8** of the borehole **7**. On the occurrence of such contact, the rotational speed of the drill bit **5** will be reduced in consequence of the friction that arises between the drill bit **5** and the bottom portion **8**. The thread **42** of the stem **44** may then be screwed along the helical guide **32** of the housing **22** from the position that is shown in FIG. **4** and, at a maximum, until the upper end portion of the thread **42** is brought into abutment against the second ledge **28'** as shown in FIG. **5**. As this axial movement between the housing **22** and the telescoping device **40** happens as a result of the rotational movement between the telescoping device **40** and the housing **22**, the piston **46** which is attached to the stem **44** will be moved axially upwards along the pipe **48** in the first chamber **28**. Consequently, the main spring **51** will be compressed. At the same time, the compression of the counterspring **56** will be reduced, and the second pressure plate **54** will be driven downwards by the counterspring **56** until the second pressure plate **54** has been moved into abutment against the shoulder **27** in the second chamber **26**.

If the compression of the main spring **51** continues, an external shoulder **50** on the pipe **48** will be brought into abutment against the first pressure plate **52** and, through this, compress the counterspring **56** against the second pressure plate **54** which, in its turn, has been brought into abutment against the shoulder **27** in the lower end portion of the chamber **26**. As mentioned, the pressure plates **52**, **54** run freely on the pipe **48**, but are prevented from moving in the longitudinal direction beyond the shoulder **50** of the pipe **48** and the shoulder **27**. Consequently, a further compression of the main spring **51** will require concurrent compression of the counterspring **56**.

The effect of the regulating device **20** shown in FIGS. **4** and **5** is thus the same as that of the regulating device shown in FIGS. **2** and **3**, namely a quicker response, substantially without said threshold value and, at the same time, a considerable increase in the maximum load during drilling.

In the exemplary embodiments shown in FIGS. **2-5**, the counterspring **56** and the pressure plates **52**, **54** are in a position nearest to the main spring **51** when the regulating device **20** in its most extended position, and in a position the furthest away from the main spring **51** when the regulating device **20** is in its most retracted position.

In an alternative embodiment (not shown), the spring **56** in the second chamber **26** shown in FIGS. **4** and **5**, for example, may be completely or partially replaced by a biasing element provided by means of a compressible fluid such as a gas. In such an embodiment, the pressure plates **52**, **54** would have to be provided with external and internal ring seals to seal against the wall of the chamber **26** and the pipe **48**, respectively. The pressure of a fluid chamber like that could be changed by means of suitable means known per se. Thus, the characteristics of the biasing element could easily be adapted for the drilling task before the string **1** is run into the well **7**.

Correspondingly, the spring **51** in the first chamber **28** could also be completely or partially replaced by a biasing element provided by means of a compressible fluid. In such a case, a seal could relatively easily be placed in a portion between the anchoring **60** and the housing **22** and/or between an upper portion of the pipe **48** and the housing **22**. Again, the pressure of such a fluid chamber could be changed by means of a suitable means, such as a valve device, and the characteristics of the biasing element could easily be adapted for the drilling task before the drill string **1** is run into the well **7**.

The present invention thus provides a regulating device with a considerably improved working interval with the least possible risk of damaging the drill bit **5** when it meets the contact surface which may be the bottom portion **8** of a wellbore **7**, a transition zone between two types of rock, or the beginning of a sidetrack. In the next place, a considerably improved maximum power capacity of drill bit **5** is achieved.

The invention thereby gives improved protection of sharp cutters which have been mentioned initially and which are necessary in order to drill hard rock while, at the same time, the overall capacity will be higher.

It should be noted that all the above-mentioned embodiments illustrate the invention, but do not restrict it, and persons skilled in the art may construct many alternative embodiments without departing from the scope of the dependent claims. In the claims, reference numbers in brackets are not to be regarded as restrictive. The use of the verb "to comprise" and its different forms does not exclude the presence of elements or steps that are not mentioned in the claims. The indefinite article "a" or "an" before an element does not exclude the presence of several such elements.

The fact that some features are mentioned in mutually different dependent claims does not indicate that a combination of these features cannot be used with advantage.

The invention claimed is:

1. A regulating device for use in a drill string between a drilling machine and a drill bit, the regulating device comprising:

a tubular female portion which at least partly encloses a tubular male portion;

a helical coupling between the female portion and the male portion to allow a telescoping movement of the regulating device in both directions between a fully extended position and a fully retracted position, said movement of the regulating device occurring when there is a difference in rotational speed between the female portion and the male portion;

a first biasing device which is arranged to exert a driving force to drive the regulating device towards its extended position; and

a second biasing device, wherein the second biasing device has an associated driving device whose axial position in the regulating device is controlled by mutual axial position of the male portion and the female portion, by a portion of the driving device being axially connected to the male portion, the second biasing device being axially displaceable in a second chamber which is axially defined by a shoulder and a ledge, the displacement of the second biasing device between said shoulder and said ledge being smaller than the telescoping movement of the male portion between the fully extended position and the fully retracted position,

the second biasing device being compressed by the driving device in an axial direction towards the first biasing device when the regulating device is in its extended position, and compressed in an axial direction away from the first biasing device when the regulating device is in its retracted position;

wherein the second biasing device has biasing characteristics capable of substantially balancing the forces that extends the regulating device into its extended position, when the regulating device is in its extended position.

2. The regulating device according to claim **1**, wherein the first biasing device is arranged in a first chamber in a portion of the female portion, the volume of the chamber being controlled by a piston associated with the male portion.

3. The regulating device according to claim **2**, wherein the second chamber is arranged in a portion of the female portion.

4. The regulating device according to claim **2**, wherein the second chamber is arranged in a portion of the male portion.

5. A regulating device for use in a drill string between a drilling machine and a drill bit, the regulating device comprising:

a tubular female portion which at least partly encloses a tubular male portion;

a helical coupling between the female portion and the male portion to allow a telescoping movement of the regulating device in both directions between a fully extended position and a fully retracted position, said movement of the regulating device occurring when there is a difference in rotational speed between the female portion and the male portion;

a first biasing device which is arranged to exert a driving force to drive the regulating device towards its extended position; and

a second biasing device, wherein the second biasing device has an associated driving device whose axial position in the regulating device is controlled by mutual axial position of the male portion and the female portion, by a portion of the driving device being axially connected to the male portion, the second biasing device being axially displaceable in a second chamber which is axially defined by a shoulder and a ledge, the displacement of the second biasing device between said shoulder and said ledge being smaller than the telescoping movement of the male portion between the fully extended position and the fully retracted position,

the second biasing device being compressed by the driving device in an axial direction towards the first biasing device when the regulating device is in its extended position, and compressed in an axial direction away from the first biasing device when the regulating device is in its retracted position;

wherein the first biasing device is arranged in a first chamber in a portion of the female portion, the volume of the chamber being controlled by a piston associated with the male portion; and

wherein the driving device includes a first pressure plate and a second pressure plate which are individually movable in the second chamber, the pressure plates being kept spaced apart by the second biasing device, and the movement being controlled by a rod connected to the piston.

6. The regulating device according to claim **1**, wherein the first biasing device includes a spring, and wherein the second biasing device includes a spring.

7. The regulating device according to claim **6**, wherein the first biasing device further comprises a fluid under pressure.

8. The regulating device according to claim **6**, wherein each of the springs has been selected from the group: a helical spring or a series of disc springs.

9. A method of controlling weight-on-bit on a drill bit which is connected to a drilling machine via a drill string, the method comprising placing a regulating device in the drill string between the drilling machine and the drill bit; and running the drill string into and setting the drill string and the drill bit in rotation in the borehole; and bringing the drill bit into engagement with a bottom portion of the borehole;

wherein the regulating device comprises:

a tubular female portion which at least partly encloses a tubular male portion;

a helical coupling between the female portion and the male portion to allow a telescoping movement of the regulating device in both directions between a fully extended position and a fully retracted position, said movement of the regulating device occurring when

there is a difference in rotational speed between the female portion and the male portion;

a first biasing device which is arranged to exert a driving force to drive the regulating device towards its extended position; and

a second biasing device, wherein the second biasing device has an associated driving device whose axial position in the regulating device is controlled by mutual axial position of the male portion and the female portion, by a portion of the driving device being axially connected to the male portion, the second biasing device being axially displaceable in a second chamber which is axially defined by a shoulder and a ledge, the displacement of the second biasing device between said shoulder and said ledge being smaller than the telescoping movement of the male portion between the fully extended position and the fully retracted position,

wherein the second biasing device being compressed by the driving device in an axial direction towards the first biasing device when the regulating device is in its extended position, and compressed in an axial direction away from the first biasing device when the regulating device is in its retracted position; and

wherein the second biasing device has biasing characteristics capable of substantially balancing the forces that extends the regulating device into its extended position, when the regulating device is in its extended position.

10. The method according to claim **9**, wherein the regulating device is arranged between two drill collars which are integrated in a lower portion of the drill string near the drill bit.

11. A method of controlling weight-on-bit on a drill bit which is connected to a drilling machine via a drill string, the method comprising placing a regulating device in the drill string between the drilling machine and the drill bit; and running the drill string into and setting the drill string and the drill bit in rotation in the borehole; and bringing the drill bit into engagement with a bottom portion of the borehole;

wherein the regulating device comprises:

a tubular female portion which at least partly encloses a tubular male portion;

a helical coupling between the female portion and the male portion to allow a telescoping movement of the regulating device in both directions between a fully extended position and a fully retracted position, said movement of the regulating device occurring when there is a difference in rotational speed between the female portion and the male portion;

a first biasing device which is arranged to exert a driving force to drive the regulating device towards its extended position; and

a second biasing device, wherein the second biasing device has an associated driving device whose axial position in the regulating device is controlled by mutual axial position of the male portion and the female portion, by a portion of the driving device being axially connected to the male portion, the second biasing device being axially displaceable in a second chamber which is axially defined by a shoulder and a ledge, the displacement of the second biasing device between said shoulder and said ledge being smaller than the telescoping movement of the male portion between the fully extended position and the fully retracted position,

wherein the second biasing device being compressed by the driving device in an axial direction towards the first biasing device when the regulating device is in its extended position, and compressed in an axial direction away from the first biasing device when the regulating device is in its retracted position;

wherein the first biasing device is arranged in a first chamber in a portion of the female portion, the volume of the chamber being controlled by a piston associated with the male portion; and

wherein the driving device includes a first pressure plate and a second pressure plate which are individually movable in the second chamber, the pressure plates being kept spaced apart by the second biasing device, and the movement being controlled by a rod connected to the piston.

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